Implementation of Large Imaging Calorimeters

The CALICE Programme

Development of highly granular electromagnetic and hadronic calorimeters for particle flow reconstruction in future collider experiments. Key steps:

- ***Validation*** of the concept of high granularity with physics prototypes ✓
- ***Technical realization*** of detector systems satisfying collider constraints - Technological prototypes with fully embedded electronics beam tested.
- ***Application*** of CALICE expertise and technology in running experiments e.g. CMS HGCal

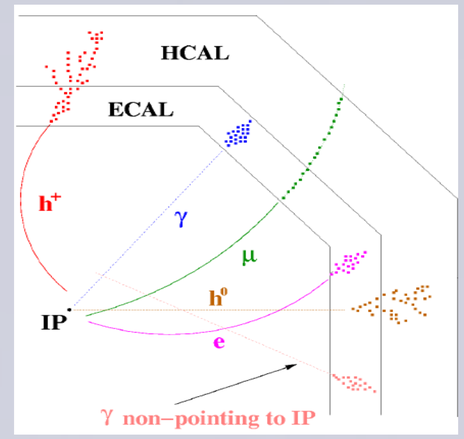
A key element: Use of ***common technologies and infrastructure***, e.g. common ASIC family (SKIROC, SPIROC, HARDROC) to facilitate combined running.

Particle Flow Calorimetry

- High sampling frequency and granularity in calorimeters to separate particle showers
- Minimal passive material between tracker and calorimeters

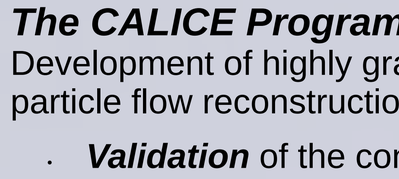
➤ Calorimeters must be inside the magnet coil

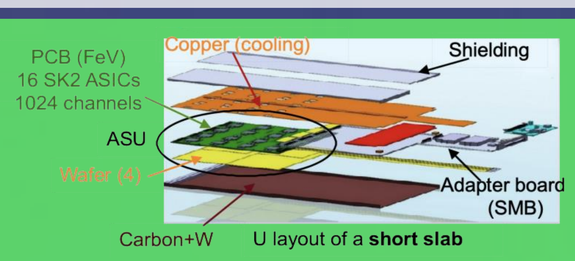
- Requires the design of very compact service electronics and active layers sensitive to the MIP level
- Requires precise mechanical assembly of the calorimeter structure allowing only small tolerances over large areas



Silicon Readout

ECAL with tungsten absorber **(SiW ECAL)**:
Silicon pads as active material
9x9 cm² wafers with 5.5x5.5 mm² cell size



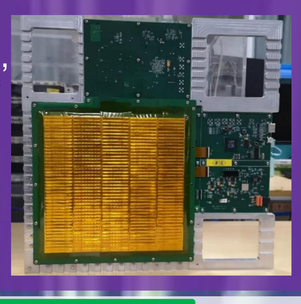


Active Signal Units (ASU's) validated at low energies
16 ASICs, 1024 channels per ASU
Full QA and assembly chain
Validation of up-scalability to slabs of 8 chained modules (barrel ECAL)

15-layer prototype, fully-embedded triggering electronics

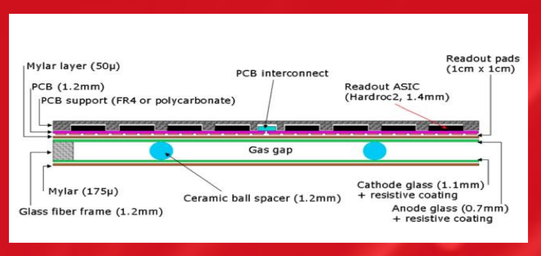
SiPM-on-Tile ECAL

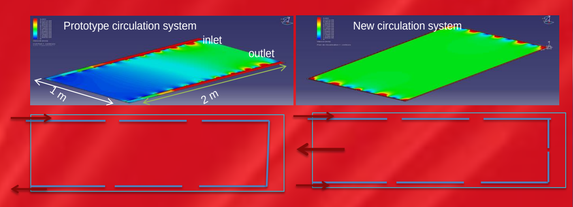
Scintillator tiles + SiPM sandwiched with tungsten absorber **(SciW ECAL)**
5x5 mm² granularity, 32 sampling layers with >6000x2 channels,
in 16 'super-layers'
LED test system used to calibrate SiPMs



Gaseous Readout

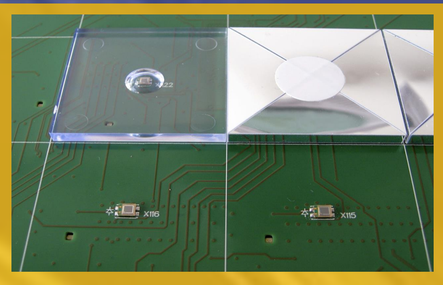
GRPC based hadronic calorimeter **(SDHCAL)**:
binary and two-bit readout
1 cm² pad size
Key developments towards scalability to full size experiments
Improved gas flow for new 1x2 m² GRPC plates
48-layer technological prototype using GRPC/electronics with steel plates

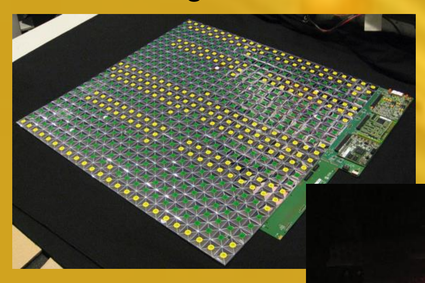




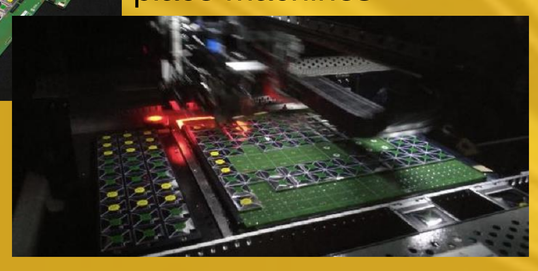
SiPM-on-Tile HCAL

Analogue HCAL **(AHCAL)**:
Scintillator tiles with individual MPPC readout
3x3 cm² segmentation



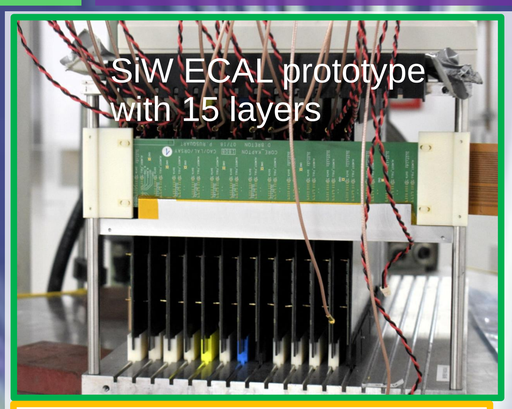


Automated assembly of large layers by pick and place machines



QA assurance of all modules
Sample testing of MPPC batches

39-layer prototype with ~22000 channels, with <0.1% dead/noisy channels.

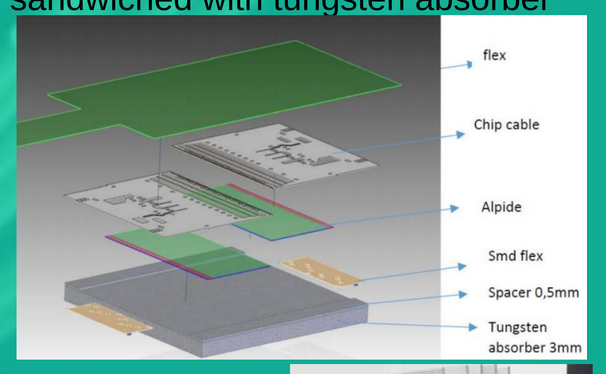


Beam Tests of Technological Prototypes

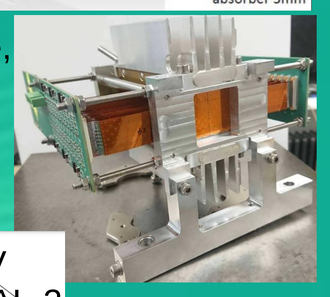
Assembly of ~1 m² prototypes with fully embedded electronics
Rigorous testing of all technologies at TB facilities at CERN/DESY

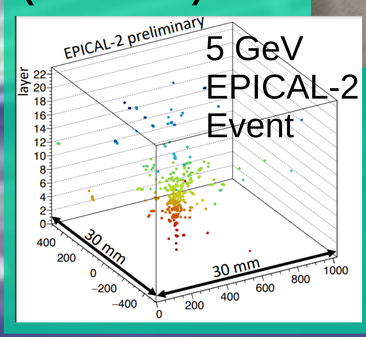
Digital Silicon ECAL

ALPIDE sensors with ultra-fine granularity (<30x27µm²) digital pixels sandwiched with tungsten absorber

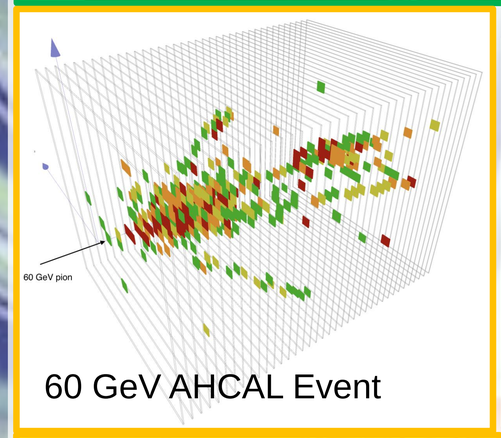


24 layer prototype, 3x3x20cm³ sensitive volume **(EPICAL-2)**

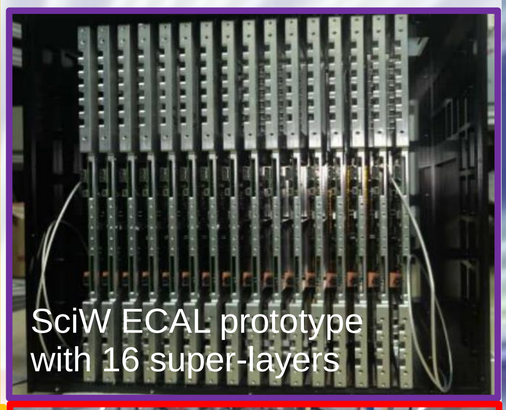


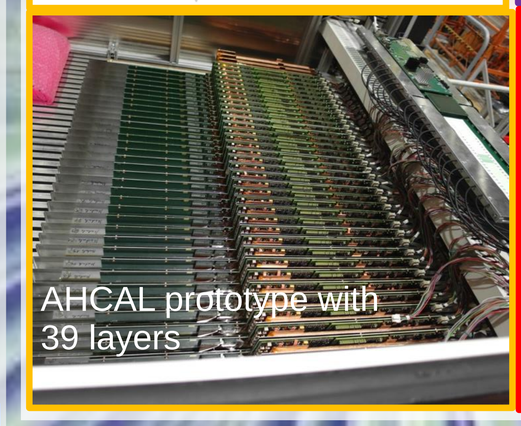


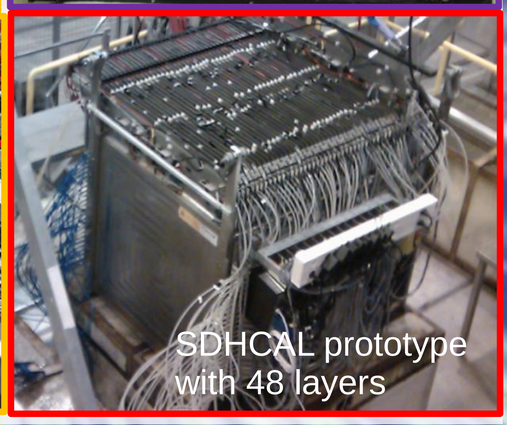
24 million pixel prototype



60 GeV AHCAL Event

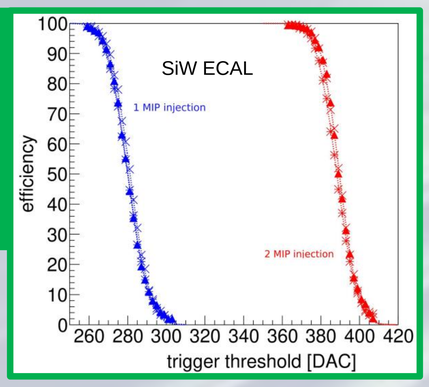


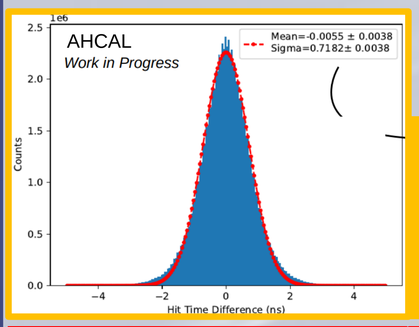




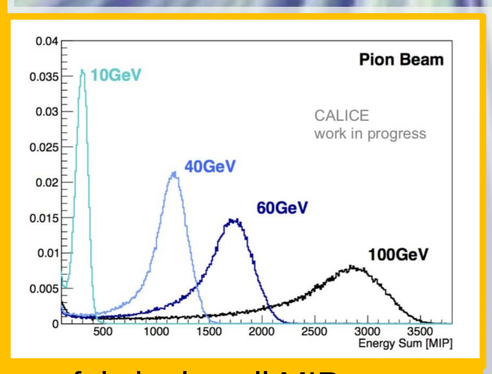
Achievements

Signal to Noise ratio $(S/N)_{trigger}$ ~12.8 in the SiW ECAL at trigger level:
- Ability to trigger on and read out small signals (MIPS) demonstrated

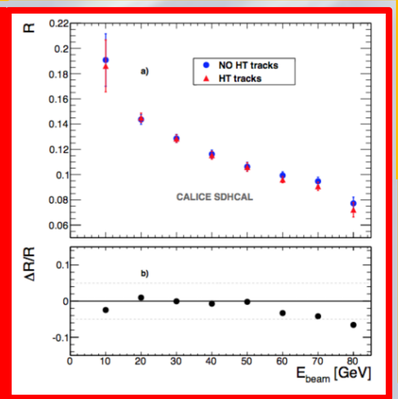




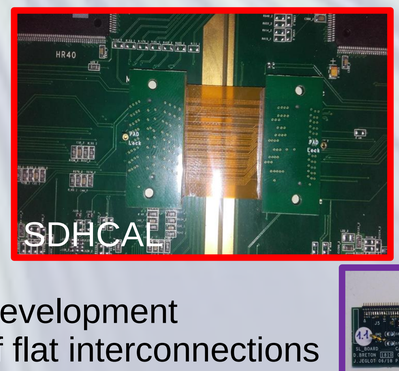
Single channel time resolution ~0.7ns for the AHCAL in test beam mode, can be reduced to ~0.5ns using time walk correction



Application of tracking using the Hough Transform technique: Correcting tracks found by the HT improves resolution and assists in electron/hadron discrimination



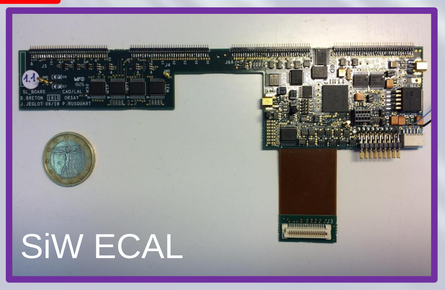
Successful single cell MIP calibration of the full AHCAL prototype: Good overall detector response. Signal to Noise ratio = $MPV_{MIPS}/\sigma_{Noise}$ ~50



Integration

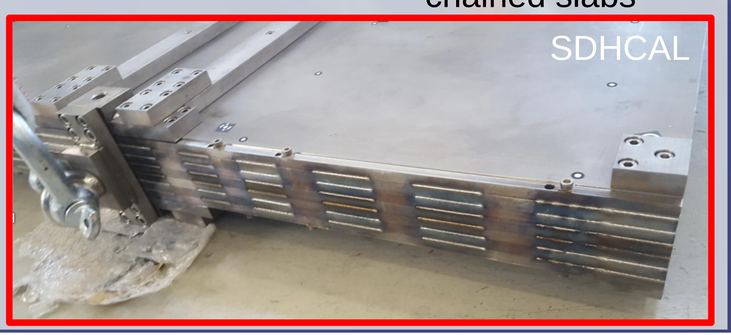
Small scale detector interfaces (DIF) as link between ASICS and DAQ system

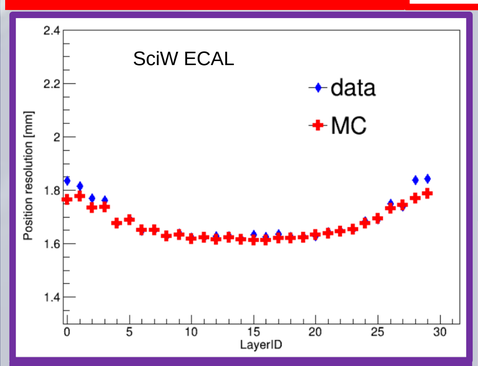
Development of flat interconnections between detector modules to facilitate compact layers



Compact SL-board and low profile connectors as interface for slow control and readout of up to 15 chained slabs

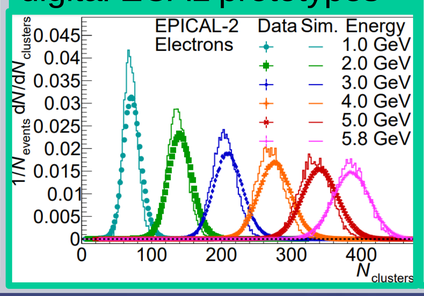
Precision mechanics to assemble structural components, e.g. Electron beam welding of absorber structure for excellent surface flatness and minimal deformation over large areas

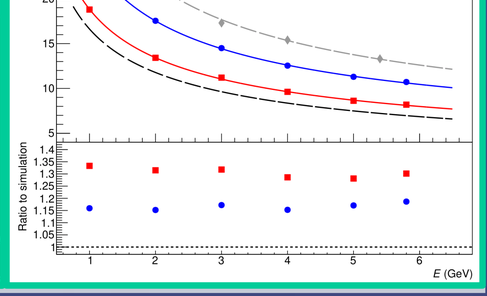




Position resolution of better than 2mm in SciW ECAL from cosmic muons

EPICAL-2 shows significant improvements in energy resolution compared to previous digital ECAL prototypes





For the CALICE Collaboration

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